Modelling continuous process for precipitated calcium carbonate production from oil shale ash

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Abstract

Global total primary energy supply, mainly relying on fossil fuels, has more than doubled between 1971 and 2012, and still accounts over 80% of the world energy supply. Both environmentally safe disposal and/or reuse of solid wastes and atmospheric emissions (CO₂, SO₂, NOx, etc) are among the most serious problems caused by the extensive use of fossil fuels for heat and power production, especially in the case of low-grade solid fuels. Due to lack of suitable applications, the majority of the alkaline industrial residues are disposed to landfill. The EU is constantly introducing stricter conditions for the emissions of greenhouse gases (GHG) and other harmful pollutants as well as new initiatives for environmental technology, waste recovery, and recycling, affecting also the oil shale based energy sector in Estonia (e.g. the goal is to reduce GHG emissions by 20-30% and annual SO₂ emissions to 25 thousand tons by 2020). CO₂ sequestration by mineral carbonation of alkaline wastes (such as oil shale ashes) mitigates both of these problems if the waste material could be upgraded to a commercial product.

In recent years the leaching behaviour of the main water-soluble compounds of oil shale ash have been studied in the context of obtaining a precipitated calcium carbonate (PCC)-type material on the basis of ash and its leaching waters. The current study focuses on the feasibility of the technologies for upgrading the oil shale ash on the basis of mathematical models (algorithms that account for both thermodynamic equilibriums and reaction kinetics) which define the operating parameters and simulate the leaching of water-soluble oil shale ash components and the crystallization of solid products in the multi-phase ash leachates – flue gas system.

The main stages of the process include: (i) leaching of the main water-soluble Ca-substances from ash and filtration; (ii) dissolution of CO₂ into alkaline liquid phase and precipitation of complex composition from ash leachate (iii) separation of PCC and liquid phase recirculation (Figure 1). The oil shale ash leaching model and the CaCO₃ precipitation model were implemented within the Aspen Plus simulation platform by inserting the reactions and corresponding thermodynamic and kinetic constants into the CSTR reactor models. The modelling work indicated that precipitated CaCO₃ can be produced with a continuously operating system, and the continuous flow carbonation experiments in a disintegrator-type reactor support that.
Figure 1. Continuous aqueous carbonisation mode on the basis of Ca-containing mineral waste

The developed methodology can be applied for CO$_2$ mineralisation as well as waste stabilization and valorisation processes in waste management sector. This tool could be used to help manage and mitigate the environmental impact of the vast inventory of such waste world-wide.